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LYCOMING

DIVISION - THE AVIATION CORPORATION

WILLIAMSPORT, 38, PENNA.

MULTI-REED VALVE COMBUSTION CHAMBER

ANALYSIS OF TEST DATA OF REPORT NO. 1097

FORM 674 15M 4 46

PAGES. PAGE

LYCOMING
DIVISION-THE AVIATION CORPORATION

REPORT NO. 1121

R E S T R I C T E D

Date of Report:

May 26, 1947

MULTI-REED VALVE COMBUSTION CHAMBER

ANALYSIS OF TEST DATA OF REPORT NO. 1097

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✓Bureau of Aeronautics (5)
Experimental File (2)
Engineering Records

R E S T R I C T E D

LYCOMING
DIVISION--THE AVIATION CORPORATION

REPORT NO. 1121

MULTI-REED VALVE COMBUSTION CHAMBER
ANALYSIS OF TEST DATA OF REPORT NO. 1097

INDEX

	Page No.
Object	1
Summary	1
Description	1
Method of Test	2-3
Results	3-4
Discussion	4-5
Selected Data Sheets #70727 Multi-Reed Valve Combustion Chamber	6-8
Curves	9-23
Curve No. 7666 - Mean Chamber Pressure vs. Fuel Flow, 29.5 PSI Abs Supply Air	9
Curve No. 7667 - Mean Chamber Pressure vs. Fuel Flow, 34.5 PSI Abs Supply Air	10
Curve No. 7668 - Mean Chamber Pressure vs. Fuel Flow, 39.5 PSI Abs Supply Air	11
Curve No. 7669 - Mean Chamber Pressure vs. Fuel Flow, Best Results at Any Speed	12
Curve No. 7670 - Combustion Efficiency vs. Fuel Flow, 29.5 PSI Abs Supply Air	13
Curve No. 7671 - Combustion Efficiency vs. Fuel Flow, 34.5 PSI Abs Supply Air	14
Curve No. 7672 - Combustion Efficiency vs. Fuel Flow, 39.5 PSI Abs Supply Air	15
Curve No. 7673 - Combustion Efficiency vs. Fuel Flow, Best Results at Any Speed	16
Curve No. 7674 - Combustion Efficiency vs. Air/Fuel Ratio, 29.5 PSI Abs Supply Air	17

INDEX Continued

	Page No.
Curve No. 7675 - Combustion Efficiency vs. Air/Fuel Ratio, 34.5 PSI Abs Supply Air	18
Curve No. 7676 - Combustion Efficiency vs. Air/Fuel Ratio, 39.5 PSI Abs Supply Air	19
Curve No. 7677 - Air Flow vs. Fuel Flow, 29.5 PSI Abs Supply Air..	20
Curve No. 7678 - Air Flow vs. Fuel Flow, 34.5 PSI Abs Supply Air..	21
Curve No. 7679 - Air Flow vs. Fuel Flow, 39.5 PSI Abs Supply Air..	22
Curve No. 7680 - Air Flow vs. Fuel Flow...........................	23

FORM 674 10M 4-48

LYCOMING
DIVISION--THE AVIATION CORPORATION

REPORT NO.

MULTI-REED VALVE COMBUSTION CHAMBER
ANALYSIS OF TEST DATA OF REPORT NO. 1097

OBJECT:

1. The object of this report is to present the results of an analysis of the data in Lycoming report No. 1097, "Initial Test of the Multi-Reed Valve Combustion Chamber, Section I, Item 3, Contract NOa(s)-4718".

SUMMARY:

2. The initial tests of the reed valve combustion chamber show a marked improvement over the rotary sleeve valve chamber previously tested. (Lycoming reports No. 1056 and 1073.)

3. Calculated mean chamber pressures up to 142% of the supply air pressure were obtained with a combustion efficiency of 48%.

4. The maximum combustion efficiency obtained was 59%. This figure has been improved during subsequent tests.

5. This chamber has not been made to function consistently at air supply pressures much above 25 psi gage.

DESCRIPTION:

6. The multi-reed combustion chamber, drawing No. 70727, which is the subject of these tests is fully described and pictured in report No. 1097.

7. The interior of the chamber is 5 inches in diameter and 22 inches long resulting in a volume of .25 cubic feet. Eighteen flat reeds of carbon steel are used in a cylindrical array. Each reed is .031 x .56 x 4.69 inches. The throat of the exhaust nozzle used for these tests is 1.06 inches in diameter. Ignition was by continuous spark from "Ford" vibrator coils. The fuel was 73 octane aviation gasoline. Timing of the cycles was accomplished by the fuel injections.

dh

METHOD OF TEST:

8. These variables were regulated. Supply air pressure, cyclic speed, and rate of fuel supplied.

9. The supply air temperature was not controlled.

10. In addition to the observed values of the above, data were taken for the determination of thrust, heat rejection to the cooling water, and air consumption.

11. A number of cards were taken with an MIT balanced diaphragm indicator and a few photographs of oscilloscope traces from a "Trimount" pressure pick-up were obtained.

12. For the purpose of this report a selection of data was made from report No. 1097. This served to reduce the runs to a convenient number and to discard obviously poor results. The basis of selection was to retain those runs having the highest ratio of thrust to mass air flow for equivalent supply air pressures, fuel air ratios and cyclic speeds. In general, all of the runs of any closely related series were retained as a unit.

13. Mean chamber pressure and apparent combustion efficiency are taken as the criteria of performance. These are calculated from the observed mean thrusts and fuel and air consumptions in accordance with the method outlined in Appendix A of report No. 1073.

14. The mean chamber pressure is taken as

$$P_m = .797 \frac{F_j}{a} + 11.55$$

where P_m = mean chamber pressure - psi abs.

F_j = observed mean jet thrust - lb.

a = area exhaust nozzle throat - sq. in.

15. The apparent combustion efficiency =

$$\eta_c = \frac{(1+m)h_2 - mh_1 + \frac{\text{Jacket Loss}}{W_f}}{CE_{FUEL}}$$

where m = air/fuel ratio

h_2 = enthalpy of products of combustion taken as air at T_2 - btu/lb.

h_1 = enthalpy of supply air -btu /lb.

CE_{FUEL} = chemical energy of fuel = 19,000 btu/lb.

W_f = fuel consumed - lb/hr

Jacket Loss - as observed - btu/hr.

$$T_2 = \left(1860\, a \frac{P_m}{W_a} \cdot \frac{m}{m+1}\right)^2$$

W_a = air consumed - lb/hr.

The enthalpies h_1 and h_2 are taken from a tabulation of air properties. The atmospheric pressure is assumed 14.5 psi.

RESULTS:

16. Plots of the calculated mean chamber pressures for 29.5, 34.5, and 39.5 supply air pressures are shown on curve sheets No. 7666, 7667, and 7668, pages, 9, 10, and 11. The curves are drawn for the best operation (highest mean pressures) without regard for cyclic speed. The curves are reproduced for comparison on curve sheet No. 7669, page 12.

17. The optimum cyclic speed is about 1,000 per minute with tendency to increase slightly with increasing fuel flows.

18. There is an upper limit to the amount of fuel which may be supplied at any given air pressure and cyclic speed and still maintain normal operation. An increase of fuel beyond this critical rate suppresses the violence of the cyclic explosions and results in a "torching" approximating constant pressure combustion. Curve sheet No. 7666, page 9, shows points for 900 and 1,000 cycles

per minute that are definitely in this "torching" condition. The cause is possibly a puddling of excess fuel in the chamber bottom.

19. Calculated combustion efficiencies are shown for the several supply air pressures on curve sheets No. 7670, 7671, and 7672, pages 13, 14, and 15. The curves are reproduced for comparison on curve sheet No. 7673, page 16. As a matter of general interest these efficiencies have been plotted against air-fuel ratios instead of fuel consumption on curve sheets No. 7674, 7675, and 7676, pages 17, 18, and 19.

20. Measured air flow versus fuel flow for the three supply pressures are shown on curve sheets No. 7677, 7678, 7679, pages 20, 21, and 22. The curves are reproduced for comparison on curve sheet No. 7680, page 23. The inordinately high air flows shown for 900 cycles on curve 7679 , page 22, appear to be associated with some malfiring or malfunctioning possibly of the fuel injection pumps. Subsequent runs have shown air flows under these same conditions compatible with the curve as drawn.

21. The curves in all cases have been drawn as envelopes defining approximately the best performance recorded, that is, drawn through the points of maximum mean pressure, maximum combustion efficiency, and minimum air flow, excluding only such points that appear discordant. That these curves generally pass through or close to corresponding data points in each case justifies this procedure.

DISCUSSION:

22. The results of these tests have been presented in the same fashion as those of the previous sleeve valve tests in report No. 1073. In this case the effects of the several variables can be separated and trends made evident.

23. The improved action of this second chamber is evidenced not only by the higher chamber pressures obtained but also by the relatively consistent data resulting from the more regular functioning.

24. The irregularity of firing at supply air pressures much above 40 psi abs. was such that usable data could not be obtained. This limitation should be further investigated. It is probable that this limiting pressure will be increased by any measures resulting in better combustion.

25. The maximum combustion efficiency of 59% leaves considerable room for improvement. Subsequent experiments with certain modifications of the chamber have shown considerably higher efficiencies. It is also expected that the projected heating of the supply air will result in a marked improvement.

26. The present supply air temperature is seldom above 150° F. because the compressors are intercooled and the manifold system has a very large cooling area. In the actual use of a combustion chamber on an engine the air discharged by the rotary compressor would have a much higher temperature which should certainly improve the vaporization of the fuel.

27. There was a remarkable freedom from valve trouble during the course of these tests. Taken together with subsequent running it appears that at least one hundred hours may be expected from the present reeds. Since this is approximately 3,600,000 cycles it is possible that by slight development the reeds may be given a very long life.

FORM 874 10M-12-45

LYCOMING
DIVISION--THE AVIATION CORPORATION

REPORT NO. 1121

SELECTED DATA
#70727 MULTI-REED VALVE COMBUSTION CHAMBER

RUN No.	AIR SUPPLY PRESS. psi abs.	AIR SUPPLY TEMP. °R	AIR SUPPLY FLOW lb/hr	SPEED CPM	FUEL lb/hr	THRUST lb	JACKET LOSS btu/hr
543	29.5	580	1533	699	34.7	23.4	45,400
544	29.5	583	1507	702	43.2	24.7	51,400
545	29.5	581	1470	703	52.6	25.1	51,600
546	29.5	579	1440	705	55.3	24.8	55,000
557	29.5	598	1517	906	35.9	25.0	51,500
558	29.5	600	1500	907	40.0	26.8	53,500
559	29.5	603	1460	908	54.5	28.4	64,100
560	29.5	603	1402	900	67.7	29.2	74,300
561	29.5	603	1380	902	74.0	29.3	73,600
562	29.5	606	1335	911	85.0	30.5	76,600
563	29.5	604	1017	899	91.5	22.3	74,000
564	29.5	602	1488	997	43.4	27.25	61,500
565	29.5	606	1448	998	51.6	28.7	60,000
566	29.5	606	1368	1002	62.7	29.3	63,400
567	29.5	602	1333	1008	78.5	30.3	63,900
568	29.5	603	1323	995	88.5	30.8	68,500
569	29.5	605	1250	1000	96.0	31.15	70,640
570	29.5	601	1008	998	99.5	22.9	63,500
571	29.5	601	1343	1111	53.4	28.1	63,500
572	29.5	599	1322	1100	64.4	29.6	69,300
573	29.5	595	1285	1102	77.3	29.9	78,500
574	29.5	597	1263	1106	82.5	30.3	79,800
575	29.5	594	1218	1112	97.6	30.8	81,000
576	29.5	592	1200	1098	103.6	31.2	84,300
577	29.5	601	1147	1106	115.0	30.0	75,400
578	29.5	591	1350	1206	49.2	27.3	62,400
579	29.5	591	1250	1211	63.4	29.0	63,700
580	29.5	591	1238	1198	72.2	29.8	73,500
581	29.5	590	1218	1203	83.2	30.1	74,900
582	29.5	590	1163	1212	102.4	29.6	77,700
583	29.5	589	1156	1200	115.0	29.6	78,400
584	29.5	588	1122	1205	131.3	28.7	69,200
380	34.5	586	1535	708	62.1	32.1	63,900
381	34.5	589	1470	708	64.7	31.1	64,600
382	34.5	581	1304	713	103.5	30.0	61,600
407	34.5	560	1830	703	36.8	30.6	56,200
408	34.5	568	1795	707	46.2	32.6	60,600
409	34.5	572	1760	710	54.0	33.6	62,000
411	34.5	578	1466	701	65.4	31.6	63,900
412	34.5	582	1710	700	55.6	33.2	59,800

FORM 874 10M-12-42

LYCOMING
DIVISION--THE AVIATION CORPORATION

REPORT NO. 1121

SELECTED DATA
#70727 MULTI-REED VALVE COMBUSTION CHAMBER

RUN No.	AIR SUPPLY			SPEED	FUEL	THRUST	JACKET LOSS
	PRESS. psi abs.	TEMP. °R	FLOW lb/hr	CPM	lb/hr	lb	btu/hr
678	34.5	523	1753	897	46.8	31.6	57,400
679	34.5	541	1710	905	58.0	33.9	74,300
680	34.5	548	1680	895	73.0	35.3	93,200
681	34.5	552	1670	900	81.7	36.1	92,200
673	34.5	565	1658	907	92.5	36.9	88,800
674	34.5	565	1632	900	100.2	37.2	91,600
675	34.5	566	1615	903	109.7	37.6	92,500
246	34.5	608	1717	995	56.7	35.6	77,800
247	34.5	609	1679	998	74.0	36.6	85,600
249	34.5	612	1612	1006	85.5	38.2	92,100
250	34.5	613	1628	1000	74.9	36.3	92,800
251	34.5	613	1566	1007	93.1	38.7	92,600
252	34.5	614	1545	1010	99.1	40.0	95,100
253	34.5	613	1513	1015	108.0	40.0	93,400
256	34.5	620	1488	995	112.0	38.6	90,800
257	34.5	619	1575	1089	65.6	35.8	84,200
258	34.5	619	1518	1114	82.5	38.0	90,400
259	34.5	617	1531	1095	86.2	40.0	94,100
260	34.5	616	1511	1095	91.4	38.9	97,200
261	34.5	615	1490	1098	100.8	39.0	97,200
262	34.5	615	1486	1102	107.0	39.2	97,500
263	34.5	614	1313	1232	127.7	37.3	86,100
276	39.5	607	2142	700	41.0	38.2	64,600
277	39.5	614	2090	703	49.0	39.6	65,200
278	39.5	622	2025	710	60.5	40.2	64,800
279	39.5	628	1940	712	67.4	39.2	66,500
280	39.5	629	1922	706	74.5	40.0	65,400
281	39.5	631	1955	704	76.7	40.4	58,400
282	39.5	632	1853	711	90.4	40.4	71,600
313	39.5	609	2290	900	57.3	42.2	78,700
314	39.5	610	2245	902	69.5	43.8	96,300
315	39.5	609	2220	903	77.1	44.9	102,700
316	39.5	609	2203	907	84.2	45.9	101,000
317	39.5	609	2175	907	86.5	46.2	101,000
318	39.5	609	2140	908	97.5	45.5	106,100
414	39.5	592	1922	1000	59.9	43.2	75,600
415	39.5	590	1952	1004	73.4	45.5	100,500
416	39.5	590	1892	1008	79.5	46.6	101,300
417	39.5	590	1887	1010	87.2	47.5	105,500

NO. 0026 TRACING PAPER, K. ELLIOTT CO., PITTSBURGH

FORM 674 10M-12-42

LYCOMING
DIVISION--THE AVIATION CORPORATION

REPORT NO. 1121

SELECTED DATA
#70727 MULTI-REED VALVE COMBUSTION CHAMBER

RUN No.	AIR SUPPLY			SPEED	FUEL	THRUST	JACKET LOSS
	PRESS. psi abs.	TEMP. °R	FLOW lb/hr	CPM	lb/hr	lb	btu/hr
418	39.5	587	1868	1012	94.1	48.3	113,000
419	39.5	576	1820	1020	107.8	49.2	114,300
420	39.5	598	1812	1003	105.7	48.6	111,900
421	39.5	591	1817	1003	107.5	49.0	116,100
424	39.5	590	1755	1106	82.5	44.3	117,800
425	39.5	581	1792	1101	100.9	44.3	111,200
427	39.5	579	1763	1100	131.3	47.5	111,900
428	39.5	580	1698	1108	119.6	48.0	115,000
429	39.5	588	1738	1100	109.8	47.5	112,400

1.06 DIA NOZZLE

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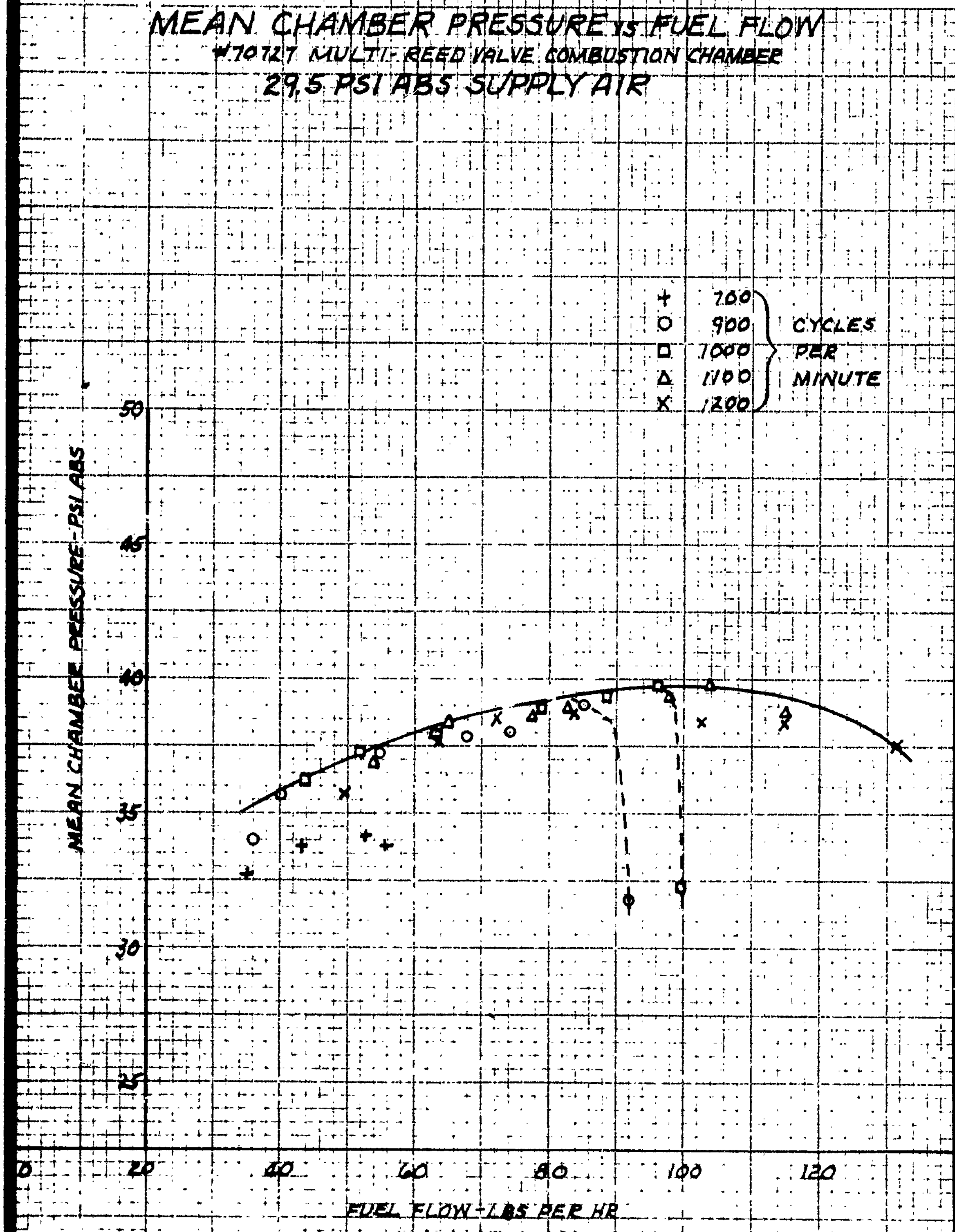
Division - The Aviation Corporation

REPORT NO. 1121
CURVE NO. 7666



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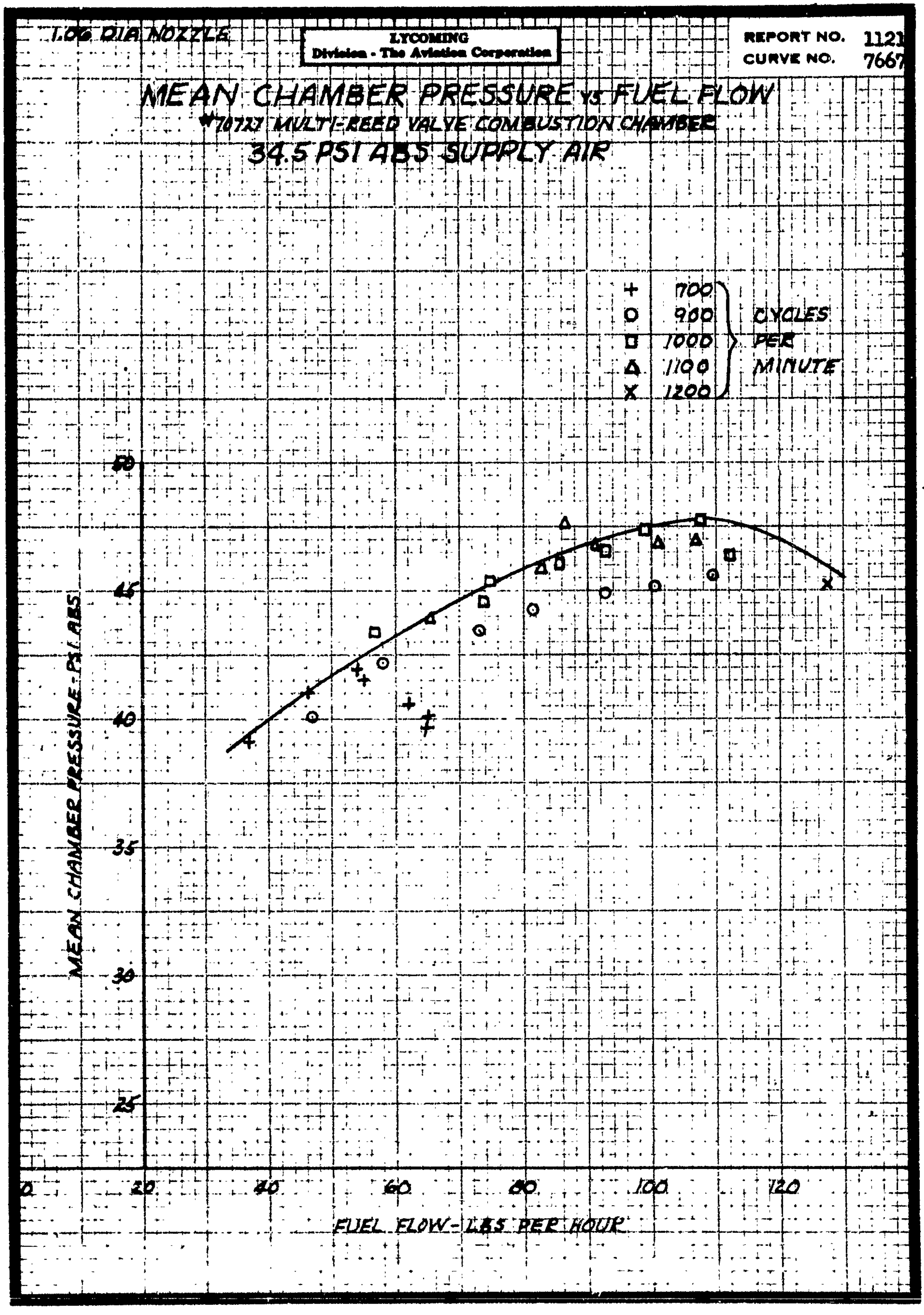
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LYCOMING
Division - The Aviation Corporation
REPORT NO. 1121
CURVE NO. 7667
MEAN CHAMBER PRESSURE vs FUEL FLOW
#70723 MULTI-REED VALVE COMBUSTION CHAMBER
34.5 PSI ABS SUPPLY AIR
+ 700
O 900
□ 1000
Δ 1100
X 1200
CYCLES PER MINUTE
MEAN CHAMBER PRESSURE - PSI ABS
50
45
40
35
30
25
0
20
40
60
80
100
120
FUEL FLOW - LBS PER HOUR

1.06 DIA NOZZLE

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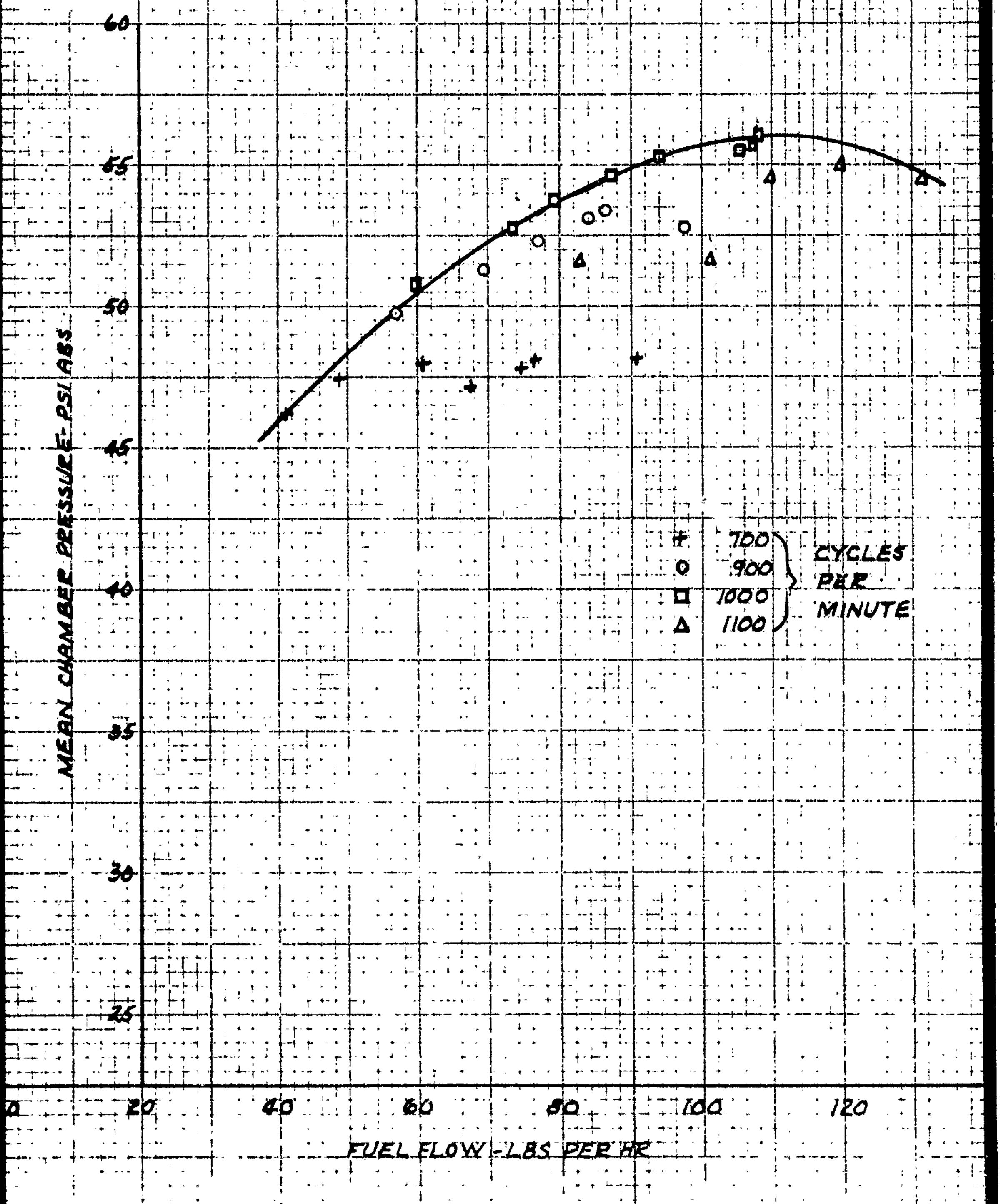
Division - The Aviation Corporation

REPORT NO. 1121
CURVE NO. 7668

MEAN CHAMBER PRESSURE vs FUEL FLOW
#70727 MULTI-REED VALVE COMBUSTION CHAMBER
39.5 PSI ABS SUPPLY AIR



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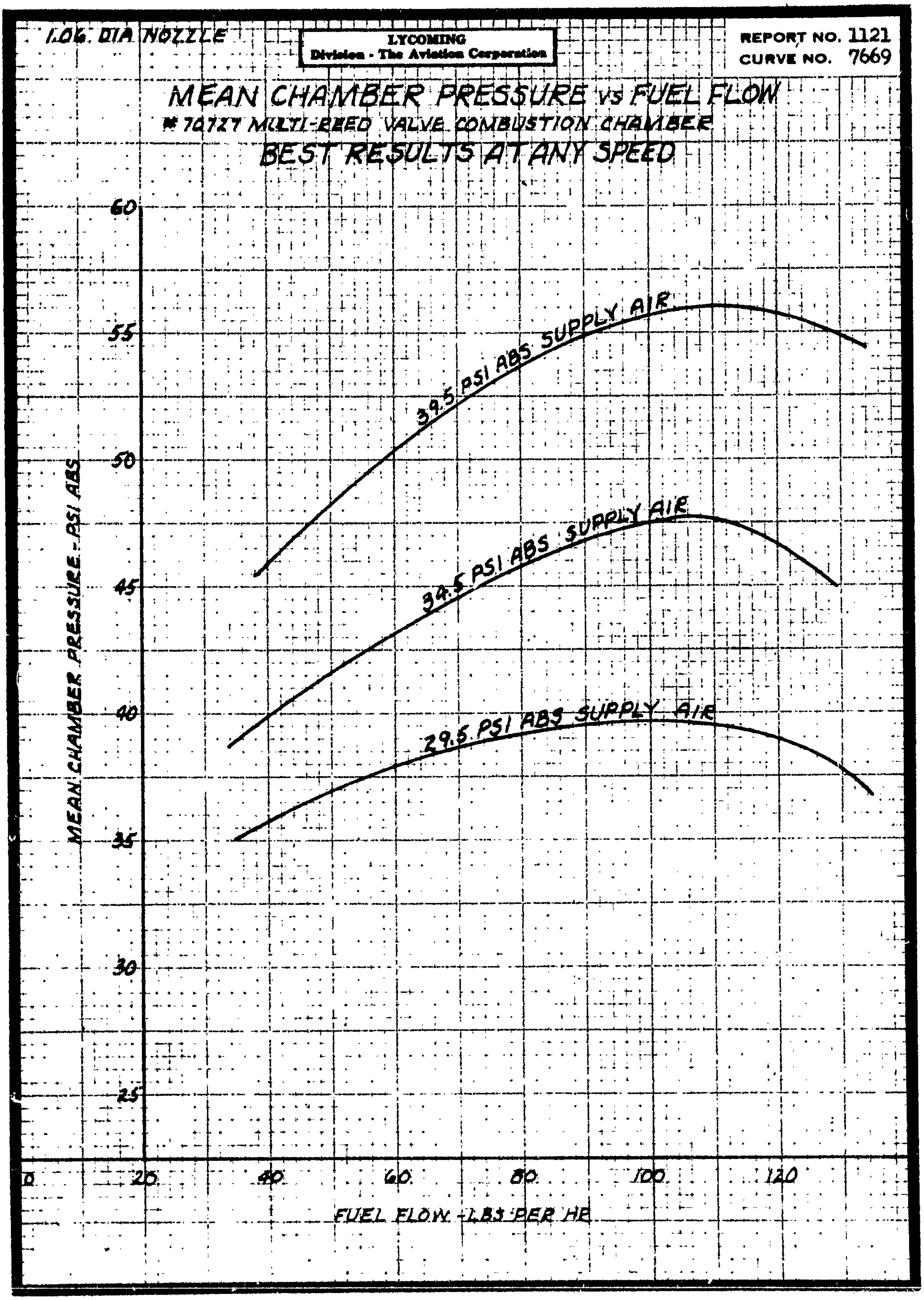
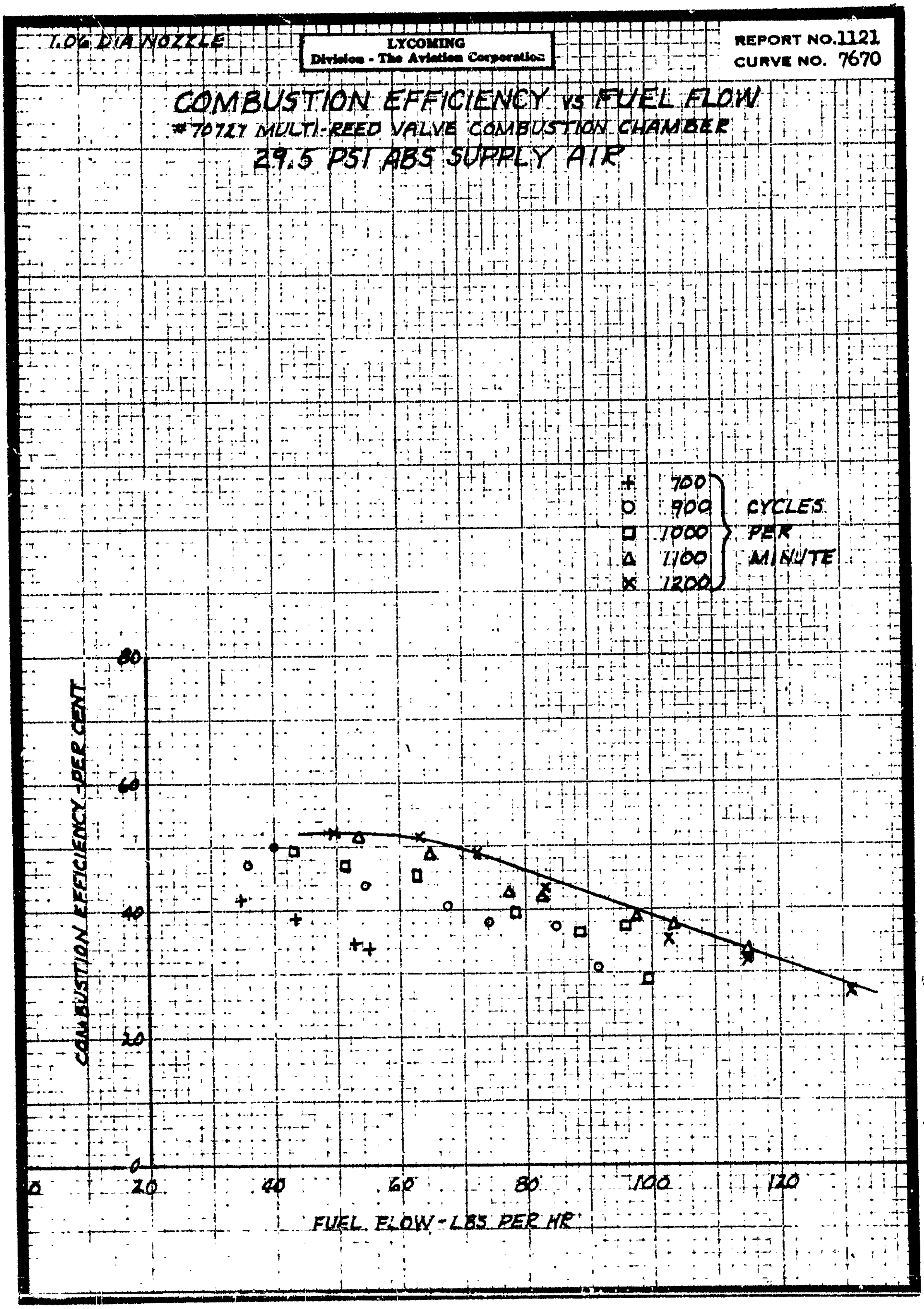
CURVE NO. 7669

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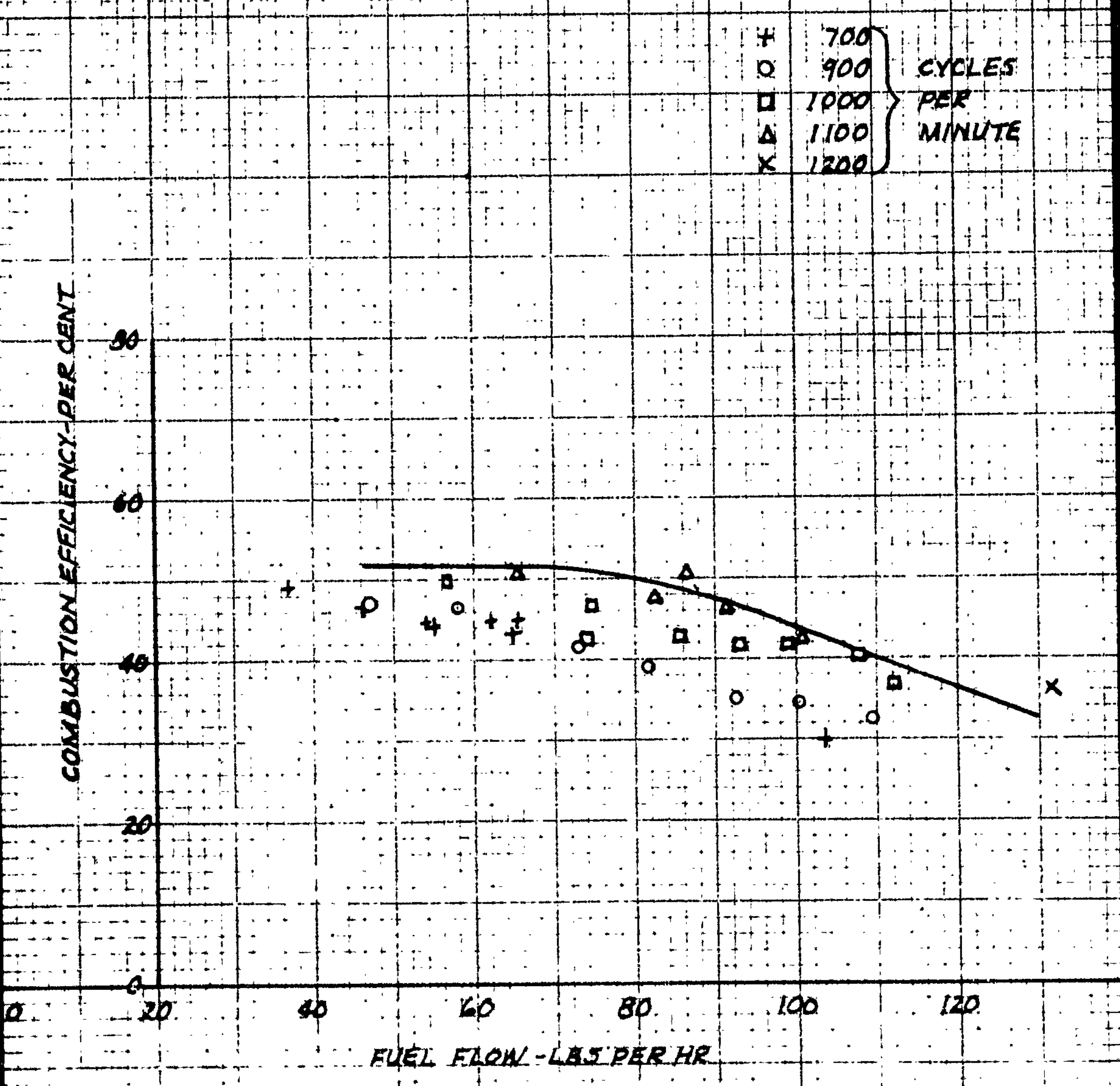
Division - The Aviation Corporation
REPORT NO. 1121
CURVE NO. 7670
COMBUSTION EFFICIENCY vs FUEL FLOW
#70727 MULTI-REED VALVE COMBUSTION CHAMBER
29.5 PSI ABS SUPPLY AIR
+ 700
○ 900
□ 1000
Δ 1100
✕ 1200
CYCLES PER MINUTE
COMBUSTION EFFICIENCY - PER CENT
0
20
40
60
80
FUEL FLOW - LBS PER HR
0
20
40
60
80
100
120

LYCOMING
Division - The Aviation Corporation

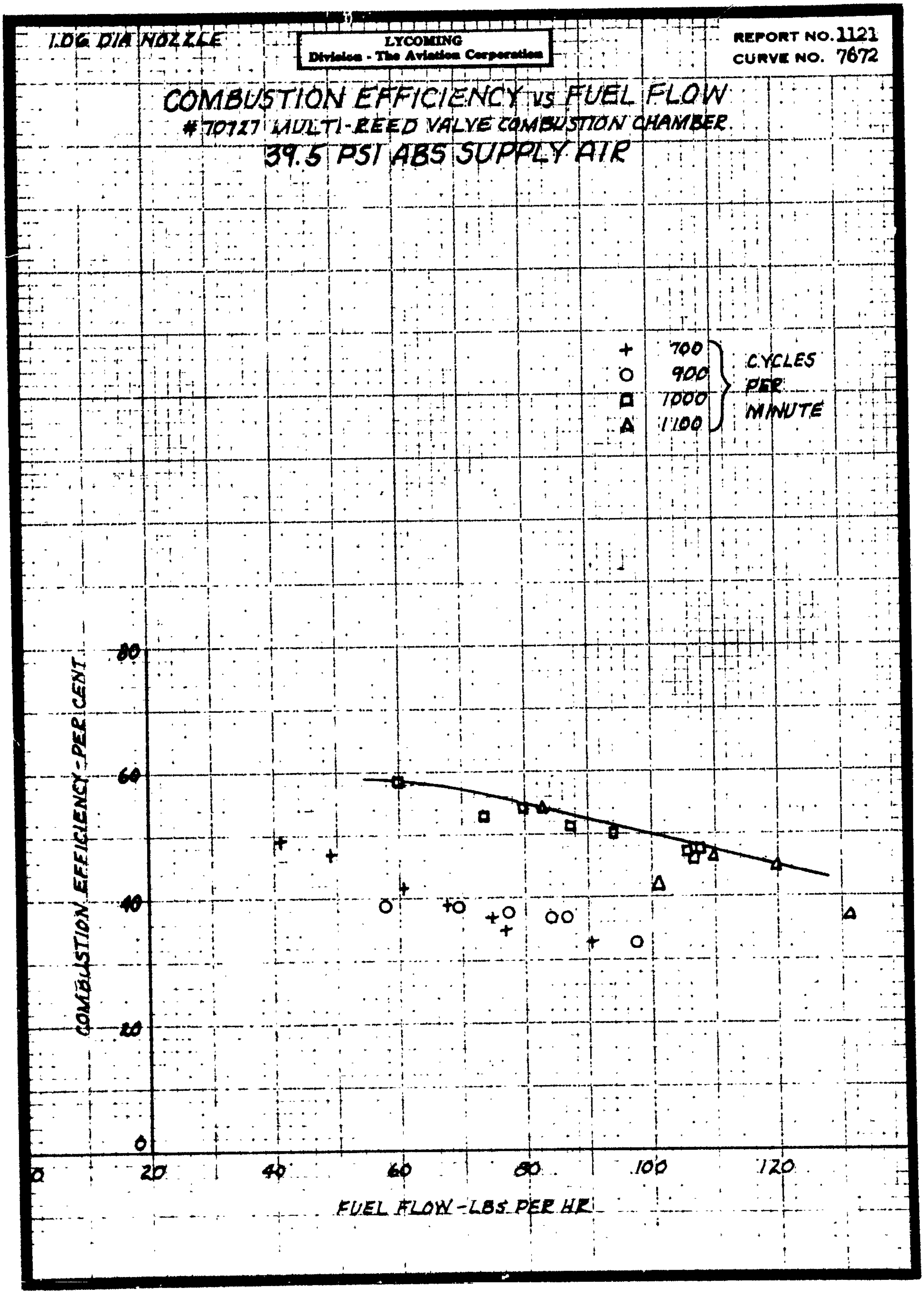
REPORT NO. 1121
CURVE NO. 7671

1.06 DIA NOZZLE

COMBUSTION EFFICIENCY vs FUEL FLOW
#70727 MULTI-REED VALVE COMBUSTION CHAMBER
34.5 PSI ABS SUPPLY AIR



REPORT NO. 1121
CURVE NO. 7672



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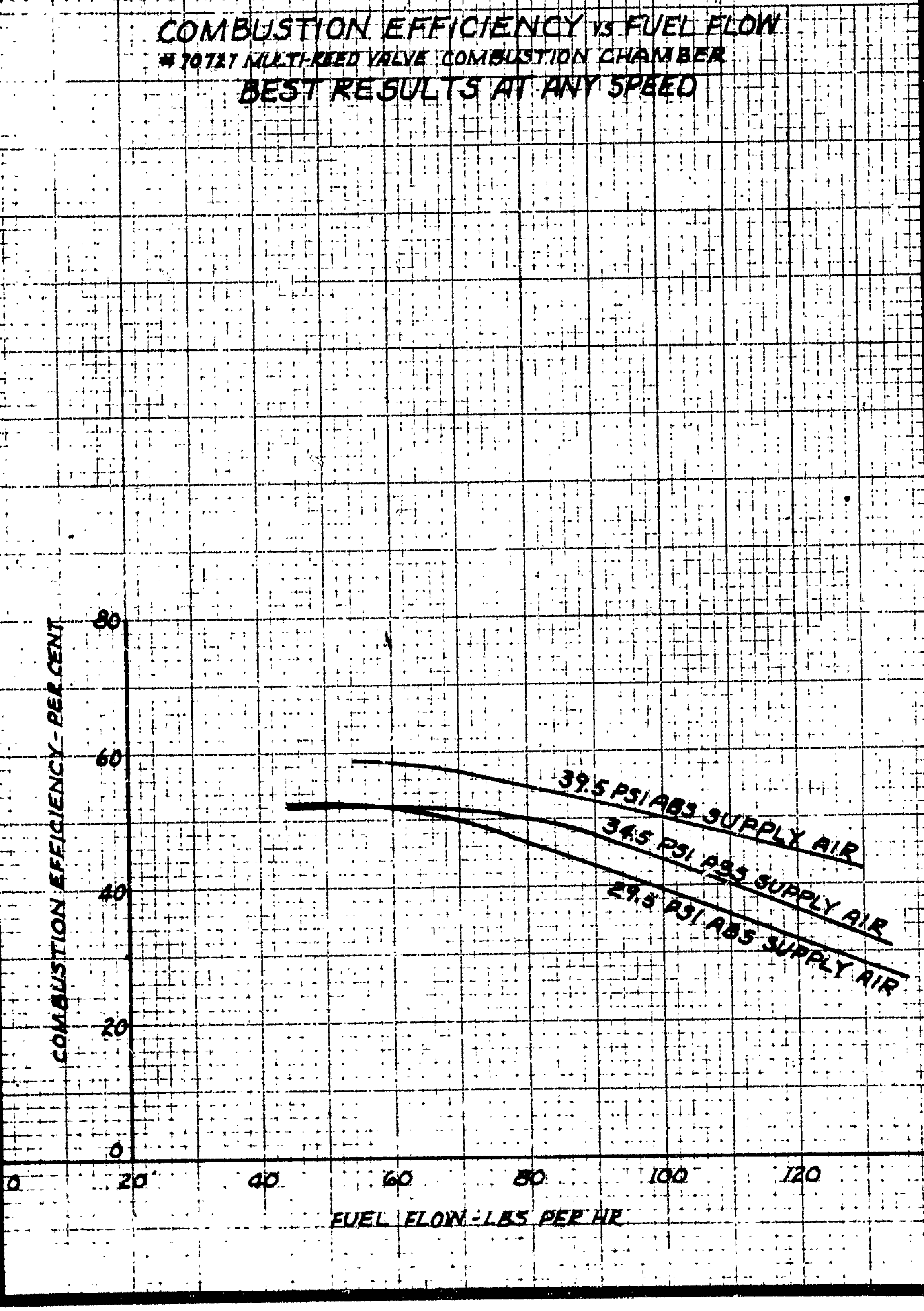
REPORT NO. 1121
CURVE NO. 7673



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REPORT NO. 1121
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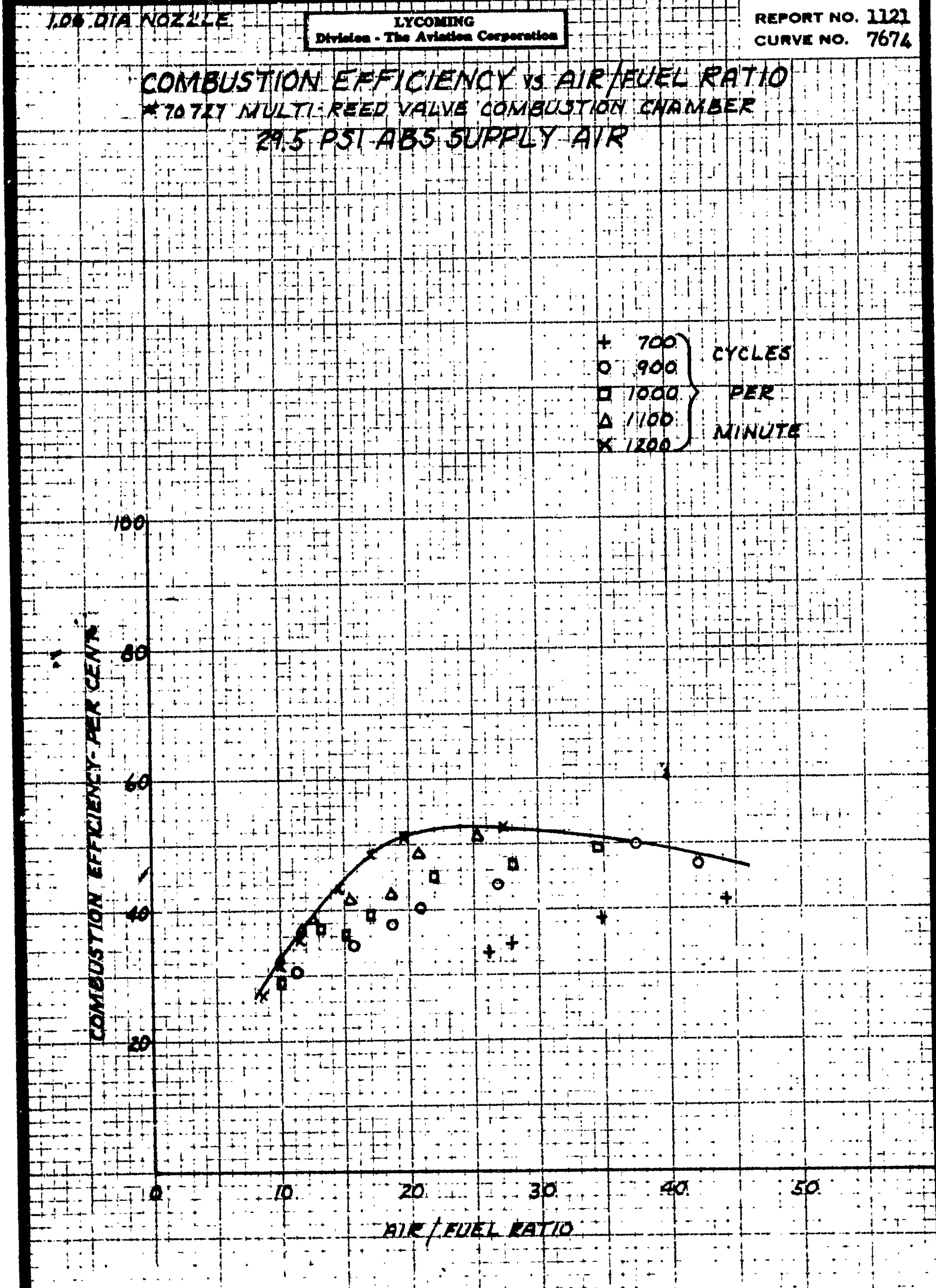

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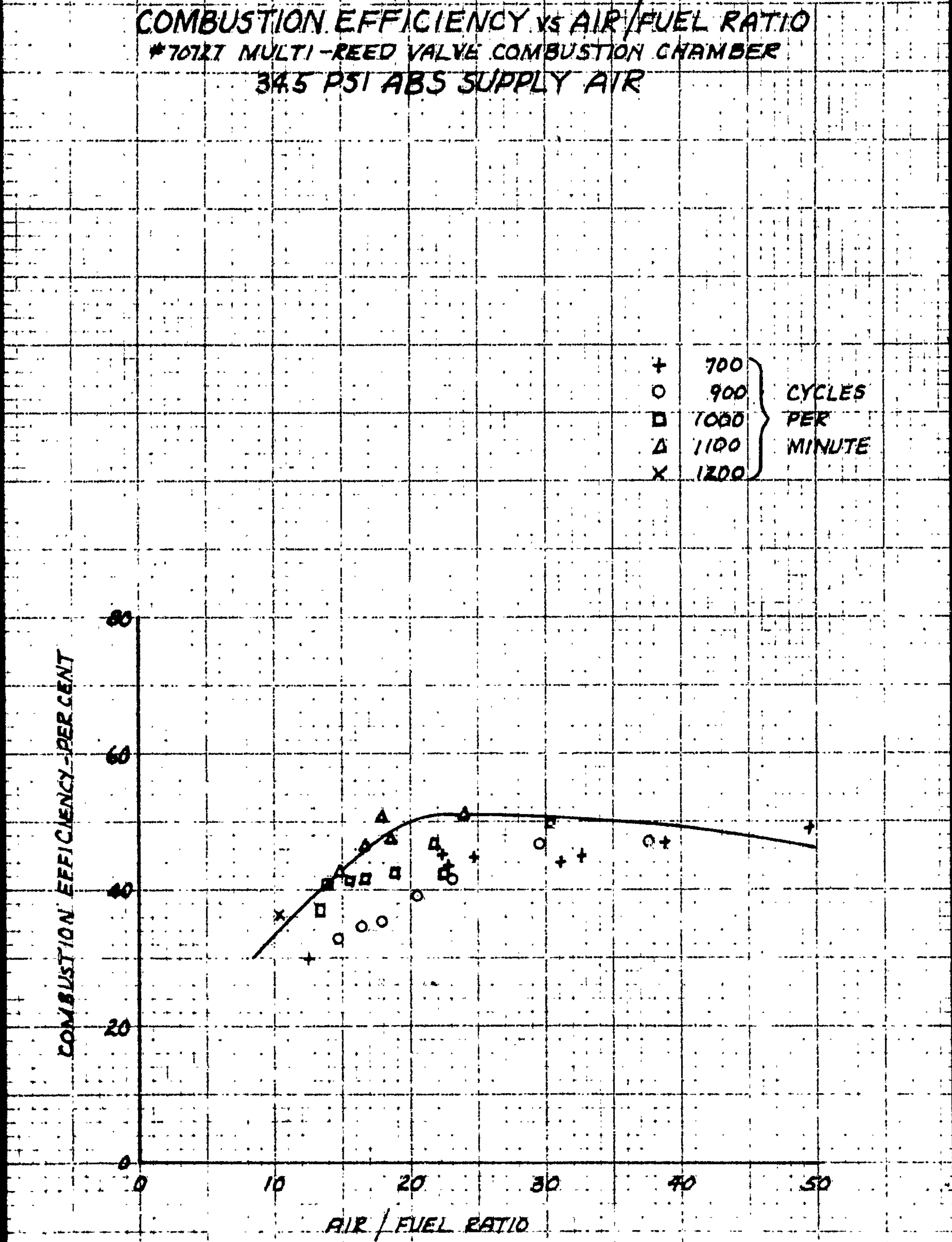
REPORT NO. 1121
CURVE NO. 7675



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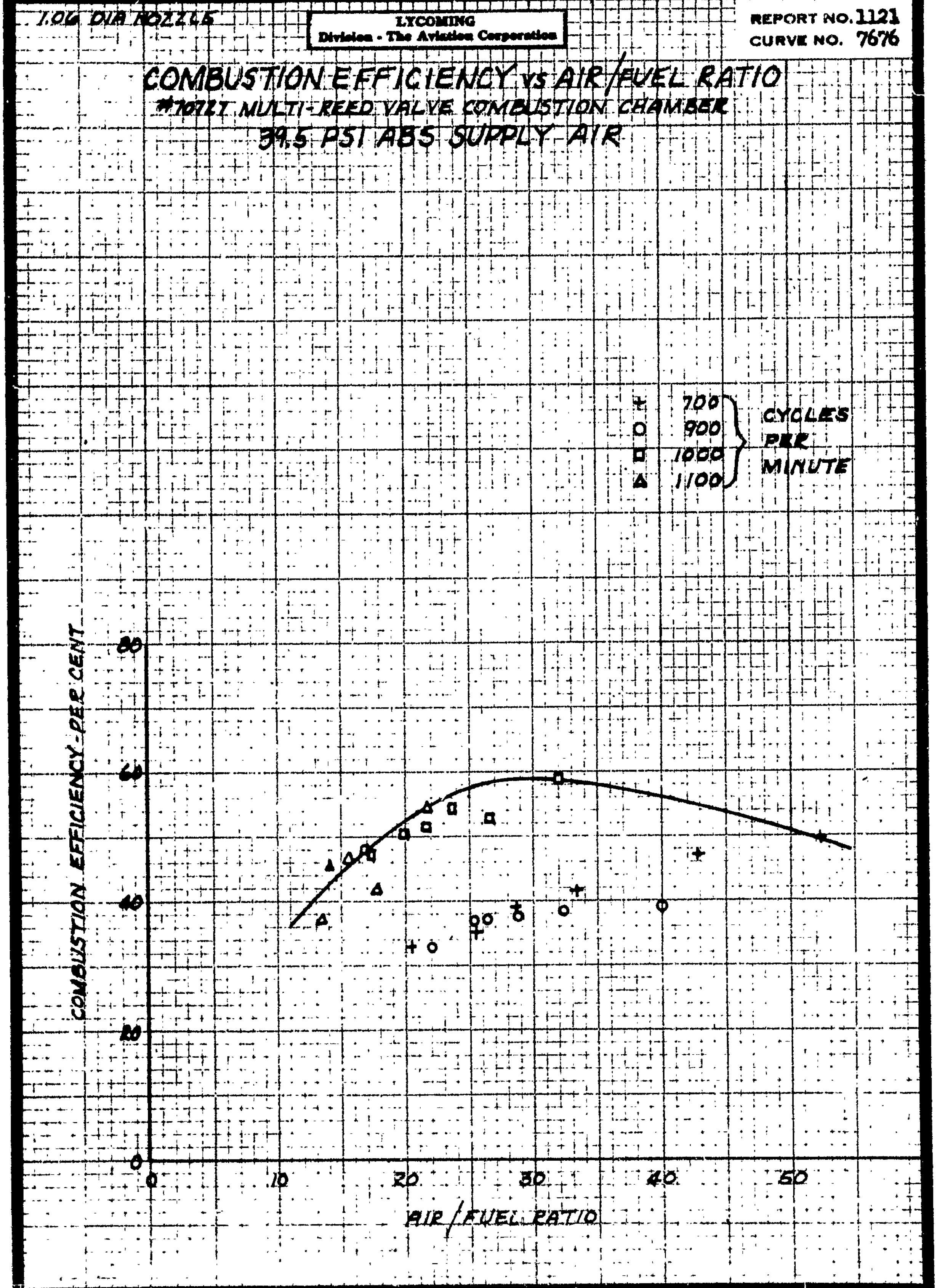
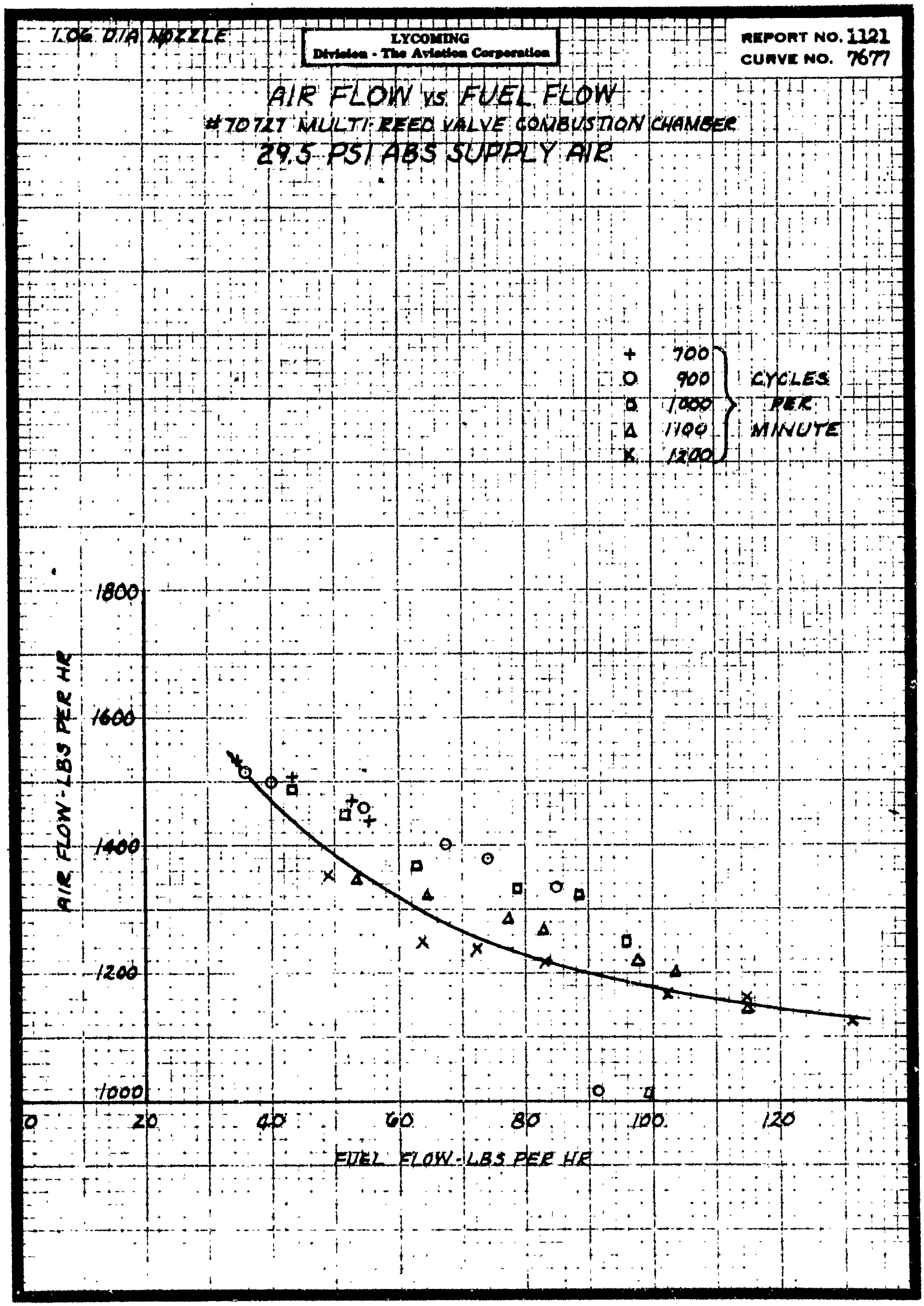
CURVE NO. 7676

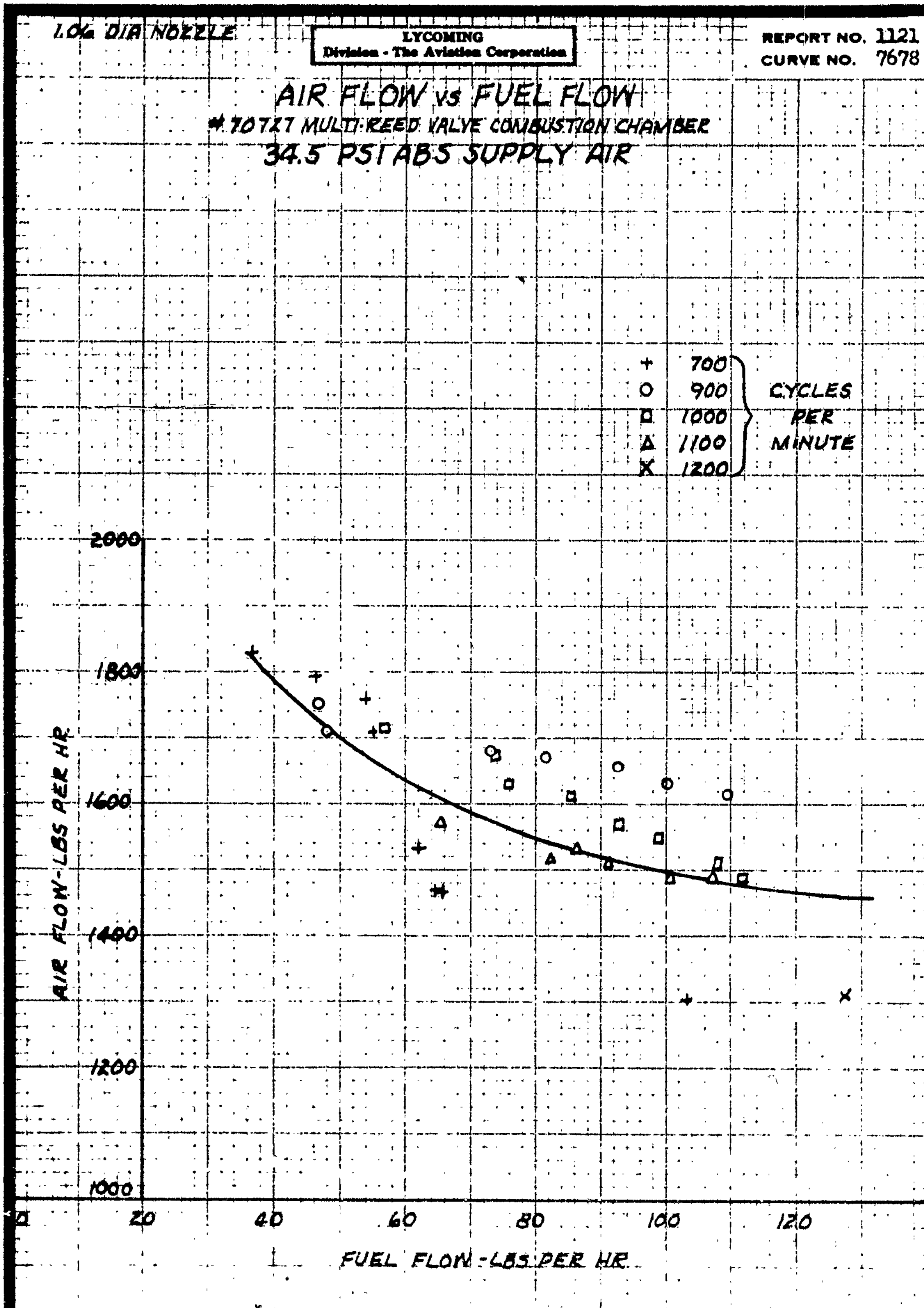


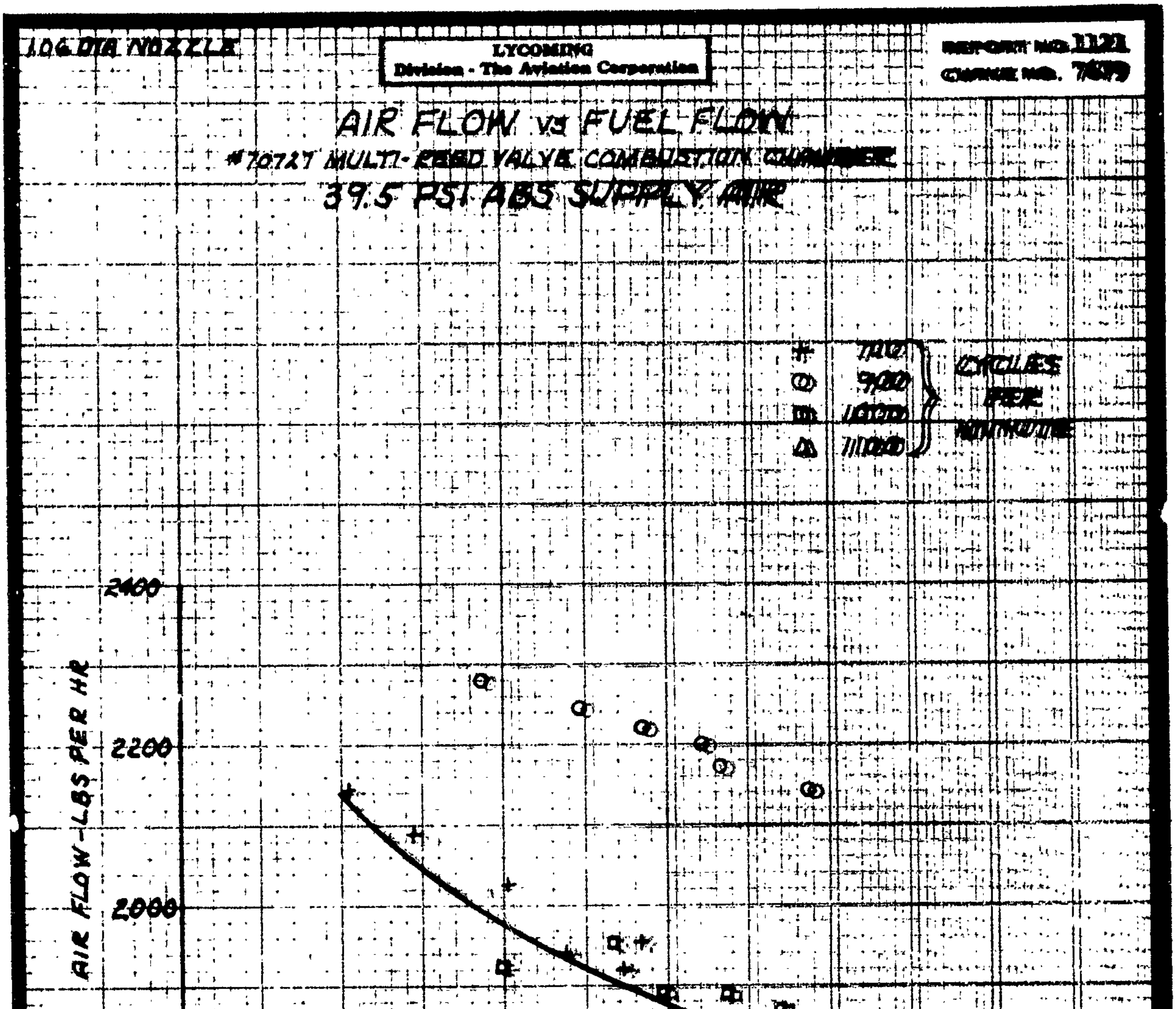

1.06 DIA NOZZLE
LYCOMING
Division - The Aviation Corporation
REPORT NO. 1121
CURVE NO. 7677
AIR FLOW vs FUEL FLOW
#70727 MULTI-REED VALVE COMBUSTION CHAMBER
29.5 PSI ABS SUPPLY AIR
+ 700
O 900
□ 1000
Δ 1100
X 1200
CYCLES PER MINUTE
AIR FLOW - LBS PER HR
1800
1600
1400
1200
1000
0
20
40
60
80
100
120
FUEL FLOW - LBS PER HR

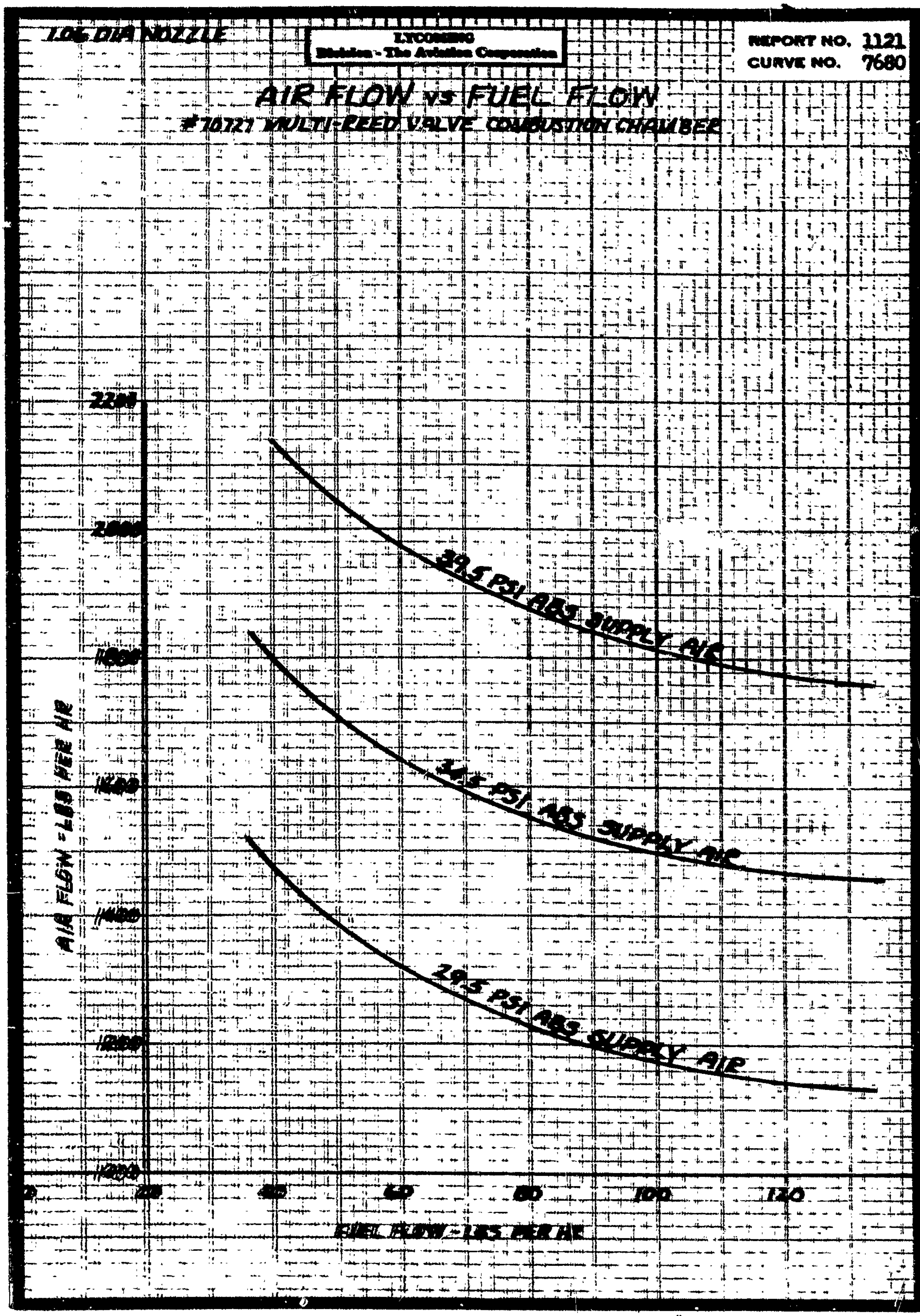
FORM-673A

LYCOMING
Division - The Aviation Corporation

REPORT NO. 1121
CURVE NO. 7678




1.06 DIA NOZZLE
LYCOMING
Division - The Aviation Corporation
REPORT NO. 1121
CHARGE NO. 7679
AIR FLOW vs FUEL FLOW
#70727 MULTI-REED VALVE COMBUSTION CHAMBER
39.5 PSI ABS SUPPLY AIR
700
900
1000
1100
CYCLES PER MINUTE
2400
2200
2000
1800
1600
AIR FLOW - LBS PER HR
0
20
40
60
80
100
120
FUEL FLOW - LBS PER HR


1.06 DIA NOZZLE
LYCOMING
Division - The Aviation Corporation
REPORT NO. 1121
CURVE NO. 7680
AIR FLOW vs FUEL FLOW
#70727 MULTI-REED VALVE COMBUSTION CHAMBER
39.5 PSI ABS SUPPLY AIR
34.5 PSI ABS SUPPLY AIR
29.5 PSI ABS SUPPLY AIR
AIR FLOW - LBS PER HR
2200
2000
1800
1600
1400
1200
1000
20
40
60
80
100
120
FUEL FLOW - LBS PER HR